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REAL-TIME SIMULATION OF TACTICAL-TARGET BEHAVIOR WITH INTERACTI--ETC(U)
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Technical Memorandum 33-77

REAL-TIME SIMULATION OF TACTICAL TARGET BEHAVIOR WITH INTERACTIVE TRACKING

Richard S. Camden

December 1977
AMCMS Code 612716.H700011

U. S. ARMY HUMAN ENGINEERING LABORATORY

Aberdeen Proving Ground, Maryland

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This Technical Memorandum describes a set of computer programs used to demonstrate the feasibility of using computer controlled interactive graphics to study gunner tracking and firing performance against a tactically-behaving target. Using computer-generated imagery, a real-time simulated view of a moving target is presented to the gunner. Through the use of control handles and switches, he acquires, tracks and engages the target as it traverses a simulated terrain area. Gunner tracking and firing performance data is collected in real-time for later reduction and analysis.

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PREFACE

The author wishes to express his appreciation to Mr. Gordon Herald, who designed, developed, and maintained the hardware interfaces; to Dr. Neil Johnson, for his guidance and supervision; to Mr. Tom Garry and Dr. Robin Keesee, for their technical assistance in fire control and tracking behavior; and to Mrs. Colleen Dixon for her patience in preparing the manuscript. Their assistance made this study possible.

CONTENTS

REAL-TIME SIMULATION OF TACTICAL TARGET BEHAVIOR WITH INTERACTIVE TRACKING

INTRODUCTION

The US Army Human Engineering Laboratory (HEL) Command/Control Simulator (CCS) is being utilized to demonstrate the feasibility of a low cost approach of studying gunner tracking performance against a variety of tactically behaving targets in a tightly controlled experimental situation. This report describes the effort to demonstrate the feasibility of using real-time simulation to obtain pertinent human factors information about a gunner's ability to acquire, track, and engage an evasive, intermittent target. This study was undertaken to ascertain the feasibility of this approach in three areas: (1) simulating and displaying evasive, intermittent, tactical target behavior; (2) controlling important variables which are expected to affect gunner tracking performance; and (3) collecting and analyzing tracking performance data. The HEL CCS description and capabilities are described in the publication entitled, "Interactive Graphics."[1]

The basic approach was to use the present HEL CCS facility to present a simulated view of a battlefield area through which a target tank is moving. A real-time interactive computer program has been developed which will display terrain features and a target tank and allow the gunner to interact by "moving" the sight using a control stick and "firing" rounds at the target tank. The program also collects tracking error and other performance data in real-time at a high sampling rate. Figure 1 shows the experimental gunner's position which includes a cathode ray tube (CRT) display, sight control stick, magnification control footswitch, and "fire" button. Figure 2 shows the CRT display as seen by the gunner.

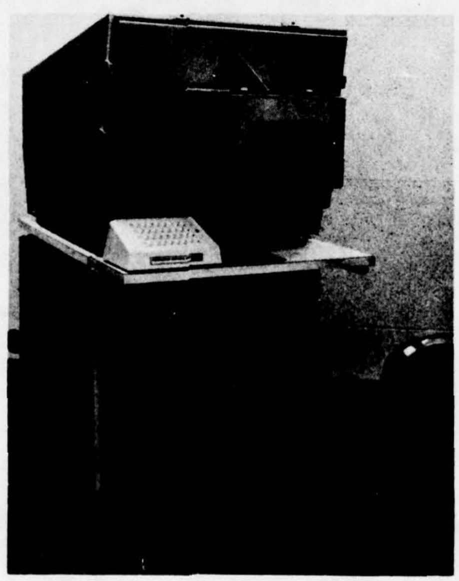

Figure 1. Gunner's position.

[1]Applied Research Team. Interactive graphics: A tool for applied human factors engineering. US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD.

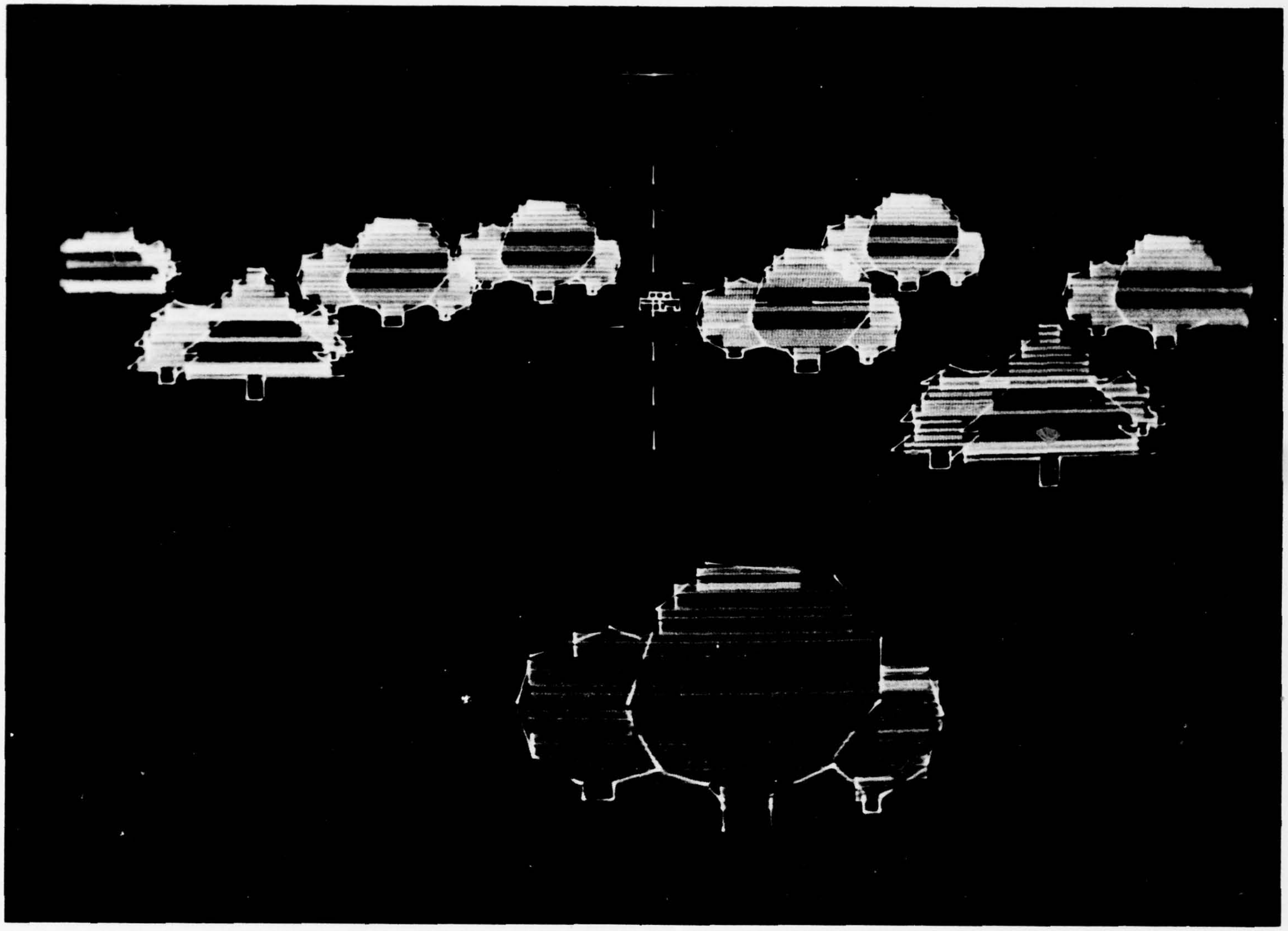

Figure 2. CRT display as seen by the gunner.

The computer program was designed and coded to provide controlled, measurable, repeatable experimental conditions and to provide maximum experimental flexibility and control over independent variables such as:

1. Speed, direction, and agility of target tanks.

2. Distribution of terrain features.

3. Type and size of terrain features.

4. Magnification of view.

5. Control stick type and transfer function.

6. Target intervisibility.

COMPUTER PROGRAM OVERVIEW

The computer programs for this simulation were written in FORTRAN and DAS assembly languages and consist of a number of related sub-elements which perform the following functions:

1. Establish a terrain area data base.

2. Develop a target tank course (scenario) through the terrain area.

3. Determine target intervisibility periods during the scenario.

4. Display and track the target tank in real-time as it traverses a course through the terrain. Collect and store tracking performance data.

5. Reduce and analyze tracking performance data.

The data bases and files utilized by the programs are managed by the computer operating system. Appendix A describes the principal computer programs developed for this study. Appendix B describes the files used in program execution.

TERRAIN AREA DATA BASE

The terrain area is considered as a flat plane 2000m x 1000m, tilted toward the observer at an angle of 5.7^{o} as depicted in Figure 3.

The terrain area is tilted so that a terrain feature will not obstruct the gunner's view for an infinite distance behind the object. The dimensions of the terrain area and the location of the observer are given in Figure 4.

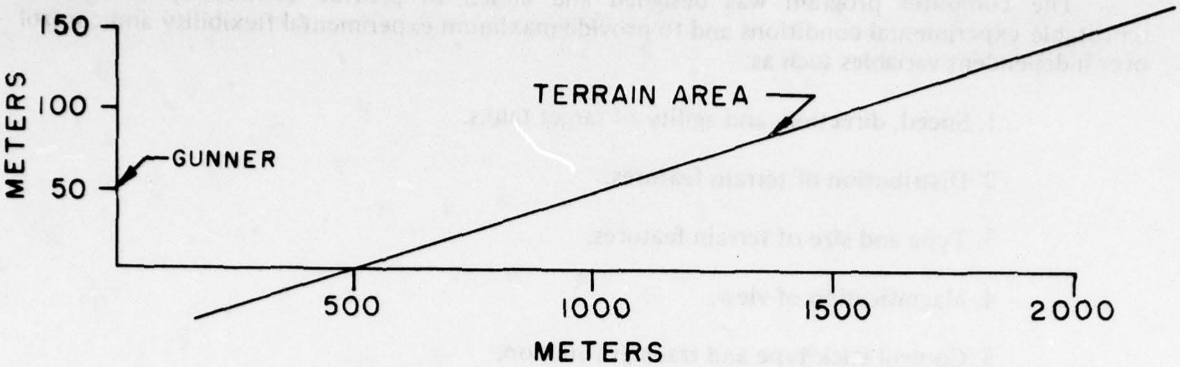

Figure 3. Terrain area orientation.

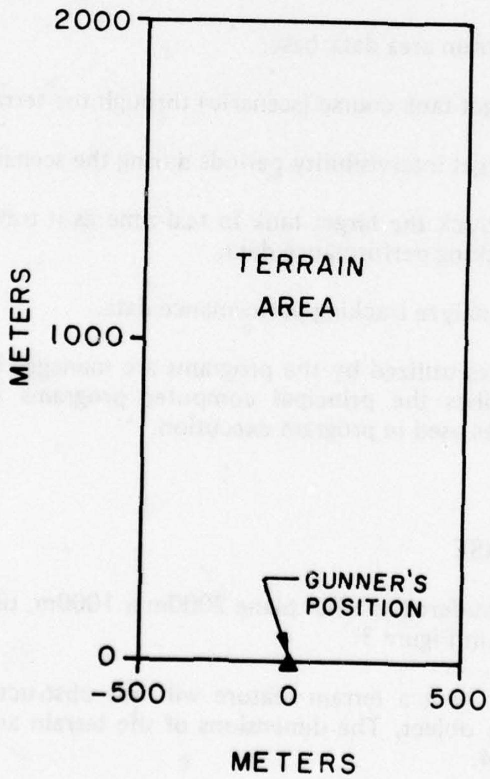

Figure 4. Terrain area.

The terrain features are laid out on the terrain area by entries in the disk file "TERRL" (global on DISK 1). For example, if a tree (type 1) is placed 100m to right of center, 1000m from the observer, the following entry should appear in "TERRL":

TABLE 1

Terrain Area Data Base Entry

TYPE	X (Meters)	Y (Meters)	Z (Meters)
TREE 1	100	0	1000

There are four terrain features currently available for use in the terrain area. Each feature is a 2-dimensional representation of an object, with no perspective depth. This precludes depicting terrain features which cover large longitudinal areas. The available terrain features are pictured in Figures 5a through 5c.

The terrain features developed for this effort are simple and representative of the type which can be used by this program. The data bases which describe these terrain features are separate files which contain up to 125 end points which outline the feature plus an index for writing, blanking, or shading a line segment. The CRT display generator has been modified so that designated horizontal lines within the terrain feature are vertically oscillated to achieve a "shading effect" which is used to more effectively mask the target tank as it moves behind a terrain feature. This is a particular problem, unique to the stroke-writing CRT, because lines, not surfaces, are displayed.

Terrain features of any type are easily defined and added to the terrain area data base to a maximum of 50 terrain features. The terrain area file "TERRL" must be operated on by the program SETY before it is used by any other program. SETY will calculate the Y coordinate of the terrain located based on the Z coordinate. All 50 entries must be included in "TERRL," with blank terrain features being described with a "0" in column 5. Table 2 is an example of a terrain area file which requires 7087 words of display file for its 31 terrain features.

TARGET TANK COURSE

After the terrain area data base has been established in the file "TERRL," the target tank course through this terrain can be generated. The program PATH is used to generate a course which is typical of an evasive, intermittent, tactically behaving target.

A target tank course consists of a series of straight line segments (legs) and turns through the terrain area. A maximum of 50 legs is permitted in a scenario. The target tank travels at a constant velocity during each leg.

Three independent variables are randomly generated for each leg of the scenario: speed, distance, and direction. A random number for each variable is generated from a normal distribution which has a known mean and standard deviation as listed in Table 3.

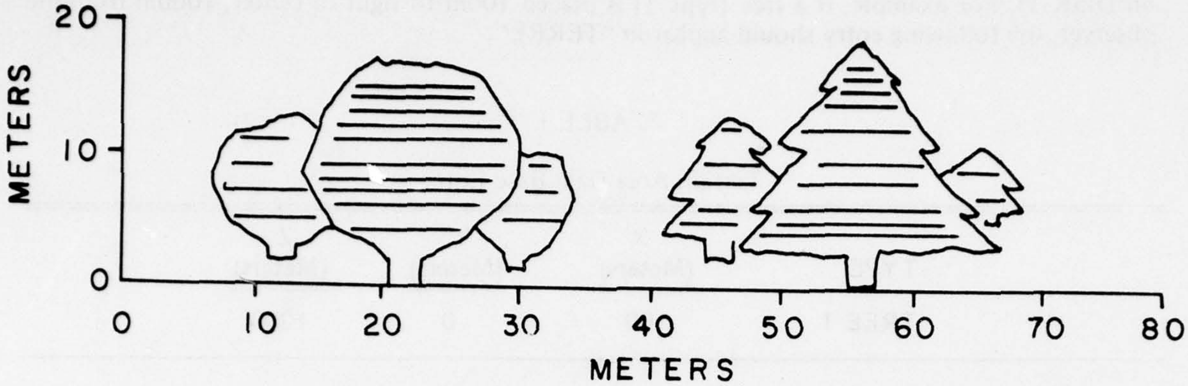

Figure 5a. Tree terrain features.

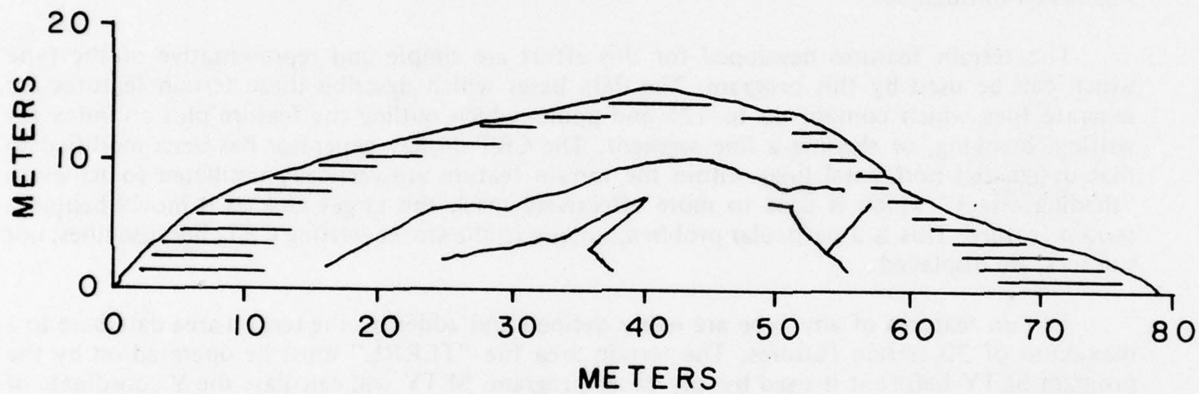

Figure 5b. Hill terrain feature.

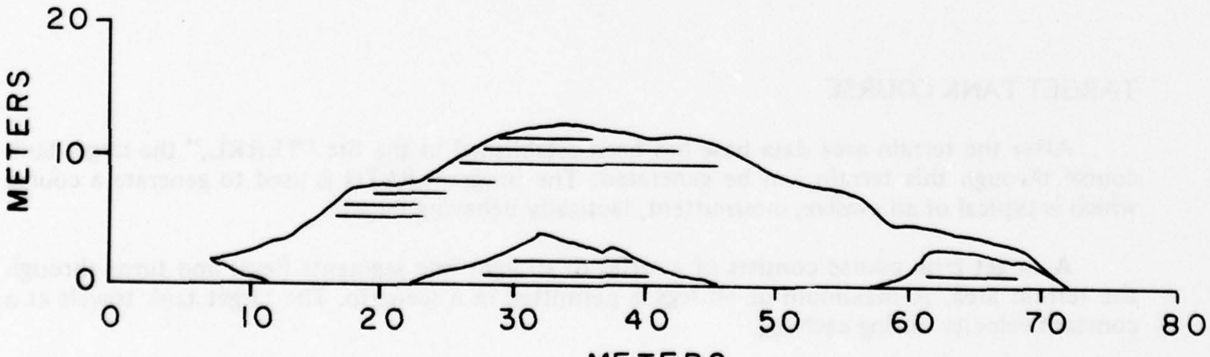

Figure 5c. Hill terrain feature.

Figure 5. Terrain features.

TABLE 2

Example of Terrain Data Base

Terrain Feature	Location (M) X	Y	Z
TREE 1	30	140	1900
HILL 3	120	136	1860
TREE 1	-30	135	1850
TREE 2	-100	130	1800
TREE 1	260	100	1500
TREE 1	200	125	1750
TREE 1	-50	120	1700
TREE 2	100	110	1600
TREE 2	220	110	1600
HILL 3	-240	110	1600
TREE 1	60	108	1580
TREE 2	-260	105	1550
TREE 2	-110	93	1430
TREE 1	-270	90	1400
TREE 2	-60	90	1400
TREE 2	70	83	1330
TREE 1	-290	80	1300
TREE 1	-240	80	1300
TREE 2	150	80	1300
TREE 1	-100	70	1200
HILL 4	300	70	1200
TREE 2	30	65	1150
TREE 2	-150	60	1100
TREE 1	200	60	1100
TREE 2	130	58	1080
TREE 1	-300	39	900
TREE 2	150	39	900
HILL 4	-100	39	900
TREE 2	60	29	800
TREE 2	110	27	780
TREE 1	0	19	700
XXXX 0	0	0	0

TABLE 3

Target Scenario Parameters

Variable	Mean	Std Dev	Minimum
Speed (km/hr)	25	7	5
Direction (deg)	$\frac{\text{Current Hdg+360}}{2}$	45	-
Distance (m)	50	25	10

PATH uses the terrain area defined in "TERRL" and generates a series of course legs, beginning at the tank starting location which is input via the teletype (TTY). The course is generated sequentially, insuring that the target path does not intersect with any terrain feature and that the target tank stays within preset left and right boundary limits. If the tank path intersects with a terrain feature during a given leg, that leg is shortened by 10 meters and the path is recalculated. If the leg distance falls below 10 meters, a new heading, distance, and speed is randomly generated. Estimates of target intervisibility are also made for each leg.

The method used to transition the tank from one leg to the next leg was developed because of program and hardware limitations. As the target tank traverses a straight line course, the target tank data base needs only to be translated before being projected to screen coordinates, which is easily done by the program while maintaining a 15 cycle/second frame rate. During a turn, however, the direction of the tank is changing so that a rotation (about x & y axes) is required in addition to the translation. Rotation is an expensive operation, particularly on a computer with no floating-point hardware, so the number of rotations must be minimized for each turn while still maintaining a smooth transition from one heading to the next.

An iterative process is used to determine the angular velocity and acceleration of the target tank during each turn. Tank speed from the previous leg is used as the speed through the turn (to a maximum of 20 kph). The randomly generated heading for the next leg determines the number of degrees in the turn. An initial value of 15^{o}/sec angular velocity (ω) is assumed. During the turn, a limitation of .3G's centripetal acceleration is adhered to. If this restriction cannot be met under the initial conditions, then a new heading is randomly generated and a new turn is calculated.

After the initial conditions are met, then iterations are applied first to lower the turning time to 4 seconds or less, then to approach a .3G turn. For each iteration, the angular velocity is increased by 7.5^{o}/sec until the turning time is less than 4 seconds. Then the iterations continue until a maximum of .3G acceleration is achieved.

This process, however, reduces low speed, small angle turns to a single segment. Therefore, the iteration is halted whenever the number of turn segments falls below 8, even though a larger acceleration would be possible. This algorithm insures that turns will be smooth, will not exceed .3G acceleration, and will not exceed 4 seconds. Following is an example of a turn resulting from this algorithm (Figure 6):

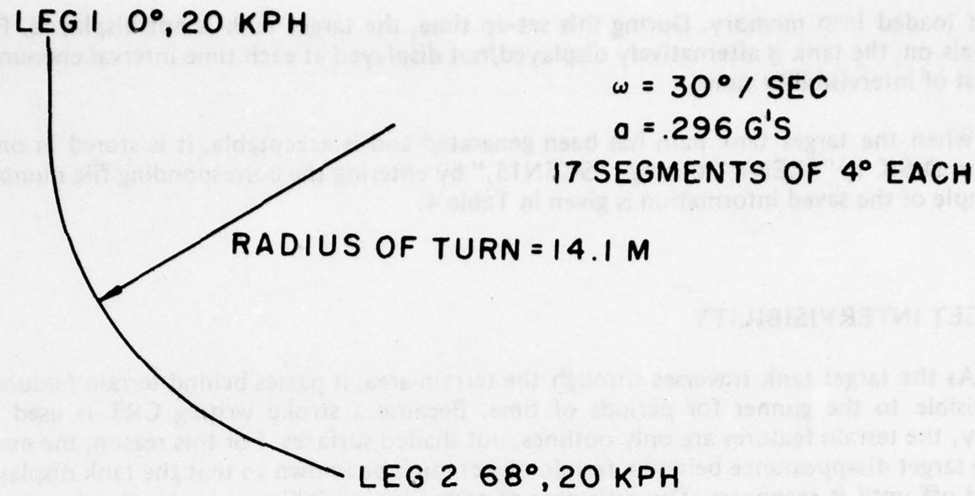

Figure 6. Tank turn derived by algorithm.

Leg 1 Speed = 20 kph
Direction = 0^{o}

Leg 2 Direction = 68^{o}

Initial conditions $\omega = 15^{o}$/second

The initial conditions yield a turning time (t) of 4.67 seconds and an angular acceleration (a) of .148 G's.

First iteration
$\omega = 22.5^{o}$/ second
$t = 70^{o}/(22.5^{o}/sec) = 3.11$ seconds
$a = .00049397V\omega = .222$ G's

Second iteration
$\omega = 30.0^{o}$/second
$t = 70^{o}/30^{o}/sec = 2.33$ seconds
$a = .296$ G's
The number of turn segments is 68^{o}/4 segments/deg = 17 segments

The unit of time measurement for the target tank movement is called a time interval and is 66 msec. This interval of time was selected because it provides for a smooth motion on the CRT (15 cycles/second) and is about the minimum amount of time required to execute all sections of the program. All target movement increments are given in units of time intervals.

The intervisibility times are also calculated by time intervals. The list of target intervisibility intervals seen in Table 4 are periods of alternating in and out of view. A bias of 80 intervals is added to these times because the first 80 time intervals are dead time to allow all the subroutines

to get loaded into memory. During this set-up time, the target tank is not displayed. From 80 intervals on, the tank is alternatively displayed/not displayed at each time interval encountered in this list of intervisibility times.

When the target tank path has been generated and is acceptable, it is stored in one of 15 files on DISK 1, "SCEN1," through "SCEN15," by entering the corresponding file number 1-15. A sample of the saved information is given in Table 4.

TARGET INTERVISIBILITY

As the target tank traverses through the terrain area, it passes behind terrain features and is not visible to the gunner for periods of time. Because a stroke writing CRT is used for this display, the terrain features are only outlines, not shaded surfaces. For this reason, the exact time of the target disappearance behind a terrain object must be known so that the tank display can be turned off until it reappears. The estimates of target intervisibility given by the program PATH are just that, estimates. To determine the precise time, a special version of the tank tracking program has been devised. The program "CHTIME" will automatically track the target tank through a given scenario, keeping the tank visible at all times, while the target tank location and terrain feature locations are simultaneously plotted on the plasma panel. The operator can press a key on the alphanumeric keyboard to record the time of target intervisibility as it proceeds through the scenario. A key press causes the program to print out (on TTY) the current scenario time (in time intervals). These times can then be entered into the intervisibility section of the target path file using the system text editor.

REAL-TIME INTERACTIVE TARGET TRACKING

The basic CRT display as seen by the gunner (Figure 2) is a perspective view of a target tank, a sight reticle, and two dimensional representations of terrain objects. These can be displayed at full or 7X scale magnification. The gunner can interact with the CRT display by using the control stick to position the reticle (effectively move the picture) over the target tank. A non-ballistic reticle used for the 7X picture is shown in Figure 7, however, the reticle configuration is programmable.

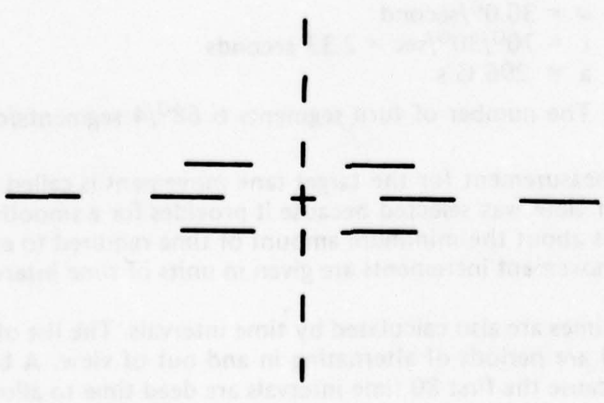

Figure 7. Reticle.

TABLE 4

Scenario Data File

TARGET STARTING LOCATION (.1 METERS)

X	Y	Z
0	1500	20000

LEG	TIME INTER-VALS	HDG	DEG/TURN SEG	TARGET MOVEMENT (.10 M/INTERVAL) DX	DY	DZ	TIME (SEC)	SPEED (KPH)	DIST (M)	PITCH (DEG)
1	80	360	0	0.0000	0.0000	0.0000	0.0	0	0	0
2	229	92	4	3.6668	-0.0319	-0.1246	15.1	20	84	360
3	127	348	-4	-0.9202	-0.5547	4.3138	8.4	24	56	5
4	78	292	-4	-4.2814	-0.2901	1.7267	5.2	25	36	2
5	44	352	4	-0.5407	-0.5867	3.8259	2.9	21	17	5
6	207	356	2	-0.4020	-0.5795	5.6884	13.7	31	118	5
7	154	20	3	1.4408	-0.4390	3.9683	10.2	23	65	5
8	161	332	-4	-2.3364	-0.5104	4.3875	10.7	27	80	5
9	31	52	4	5.0822	-1.1364	3.9775	2.1	35	20	3
10	314	360	-4	-0.0023	-0.3349	3.1219	20.8	17	98	5
11	139	10	2	1.1447	-0.6994	6.5207	9.2	36	92	5
12	99	294	-4	-3.6932	-0.2886	1.6413	6.5	22	40	2
13	101	30	4	3.2143	-0.8186	5.5777	6.7	35	65	4
14	103	78	4	4.8427	-0.1654	1.0341	6.8	27	51	1
15	85	18	-4	1.8865	-0.7237	5.8208	5.7	33	52	5
16	207	6	-2	0.3811	-0.3867	3.6523	13.7	20	76	5
17	96	110	4	2.9380	0.0332	-1.0663	6.4	17	30	359
18	344	354	-4	-0.3673	-0.3787	3.4696	22.7	19	120	5
19	99	322	-4	-3.1753	-0.4802	4.0585	6.6	28	51	4
20	211	290	-4	-2.7625	-0.1126	1.0035	14.0	16	62	1
21	49	262	-4	-2.0210	0.0242	-0.2852	3.3	11	10	360
22	158	330	4	-2.6618	-0.5108	4.6031	10.4	29	84	4
23	197	320	-2	-2.4823	-0.3110	2.9545	13.0	21	76	4
24	24	326	2	-3.7327	-0.6812	5.5256	1.6	35	16	4
25	173	324	-2	-2.9255	-0.4067	4.0202	11.5	27	86	4
26	144	284	-4	-6.6065	-0.2131	1.6427	9.5	37	98	1
27	32	224	-4	-2.1704	0.3106	-2.2492	2.1	17	10	356
28	30	242	3	-2.9435	0.2318	-1.5669	2.0	18	10	358
29	138	286	4	-4.5997	-0.1260	1.3157	9.1	26	66	1
30	248	318	4	-3.0787	-0.3580	3.4148	16.4	25	114	4
31	0	0	0	0	0	0	0	0	0	0

TARGET INTERVISIBILITY TIMES (INTERVALS)

80	191	239	332	350	524	570	1727	1774	1866
1902	2098	2143	2545	2622	2998	3178	3222	3240	3452
3501	3722	3769	10000	10000	10000	10000	10000	10000	10000
10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
10000	10000	10000	10000	10000	10000	10000	10000	10000	10000

The observer location is fixed at (0,50,0). The terrain area is described by the file "TERRL." The target tank data base is located in file "PICT" on DISK1 and consists of end points of line segments and an index indicating whether to write a blank each segment. The tank data base is given in Table 5.

TABLE 5

Tank Data Base
(.10 Meters)

INDEX	X	Y	Z	
1	-18	0	-33	TANK HULL
-1	-18	-19	-33	
-1	-9	-19	-33	
-1	-9	-12	-33	
-1	9	-12	-33	
-1	9	-19	-33	
-1	18	-19	-33	
-1	18	0	-33	
-1	-18	0	-33	
-1	-18	0	33	
-1	18	0	33	
-1	18	-19	33	
-1	18	-19	-33	
1	18	0	-33	
-1	18	0	33	
1	-18	-19	-33	
-1	-18	-19	33	
-1	-18	0	33	
1	-13	0	-12	TANK TURRET
-1	-13	0	12	
1	13	0	12	
-1	13	0	-12	
-1	-13	0	-12	
-1	-13	11	-12	
-1	-13	11	12	
-1	13	11	12	
-1	13	11	-12	
-1	-13	11	-12	
1	13	0	-12	
-1	13	11	-12	
1	13	0	12	
-1	13	11	12	
1	-13	0	12	
-1	-13	11	12	
1	0	6	-12	
0	0	15	-37	

Below is an illustration of the target tank similar to the perspective view seen on the CRT (Figure 8).

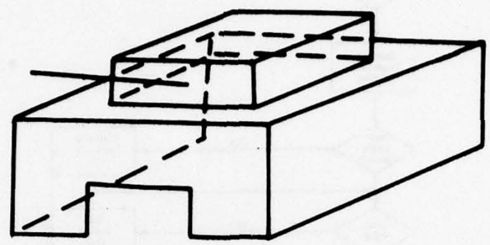

Figure 8. View of projected target tank.

The aim point on the tank is vertically in the center, between the hull and the turret. The cross sectional areas are: front= $9.7m^2$, side= $15.18m^2$. Hidden lines are not removed from the CRT presentation.

The fully magnified picture (7X) is the determining factor in the screen calibration and the viewer distance from the screen. The CRT measures 15"x19" (hxw). The horizontal field-of-view is to be 8^o; the vertical field-of-view is not a determining factor. Off-screen writing enables 1575 raster units to be utilized (-275 to 1300). With a screen size of 19", this gives a ratio of 82.9 rasters/inch. The distance from the viewer to the screen is determined by d= 9.5"/tan (4^o) = 135.8" which compresses to 19.4" (49.3 cm) because of the 7x scaling.

Depending upon the field-of-view, the full scale picture will only require a portion of the screen. A horizontal field-of-view of 30^o and a vertical field-of-view of 5^o is used describing an area of 862x140 rasters.

$$H = \tan(15^o) \times 19.4" \times \frac{82.9 \text{ rasters}}{\text{inch}} = 431 \text{ rasters}$$

$$V = \tan(2.5^o) \times 19.4" \times \frac{82.9 \text{ rasters}}{\text{inch}} = 70 \text{ rasters}$$

The key to the entire tracking effort is the computer program which provides a real-time simulation of the target behavior and provides for interaction with the gunner. The target tank tracking program runs under the control of a small mainline program which insures that real-time execution is achieved. This is done by dividing the program into functions and insuring that the most important functions are executed on a timely basis. A general flowchart of the mainline program is given in Figure 9.

The first function of the main program is to initialize all the program variables, read in all the necessary files, access the scratch file for data collection, set up the plasma panel plan position display, establish the display file and halt when ready to continue. All subsequent events are real-time and hence must be assigned to one of three priority levels.

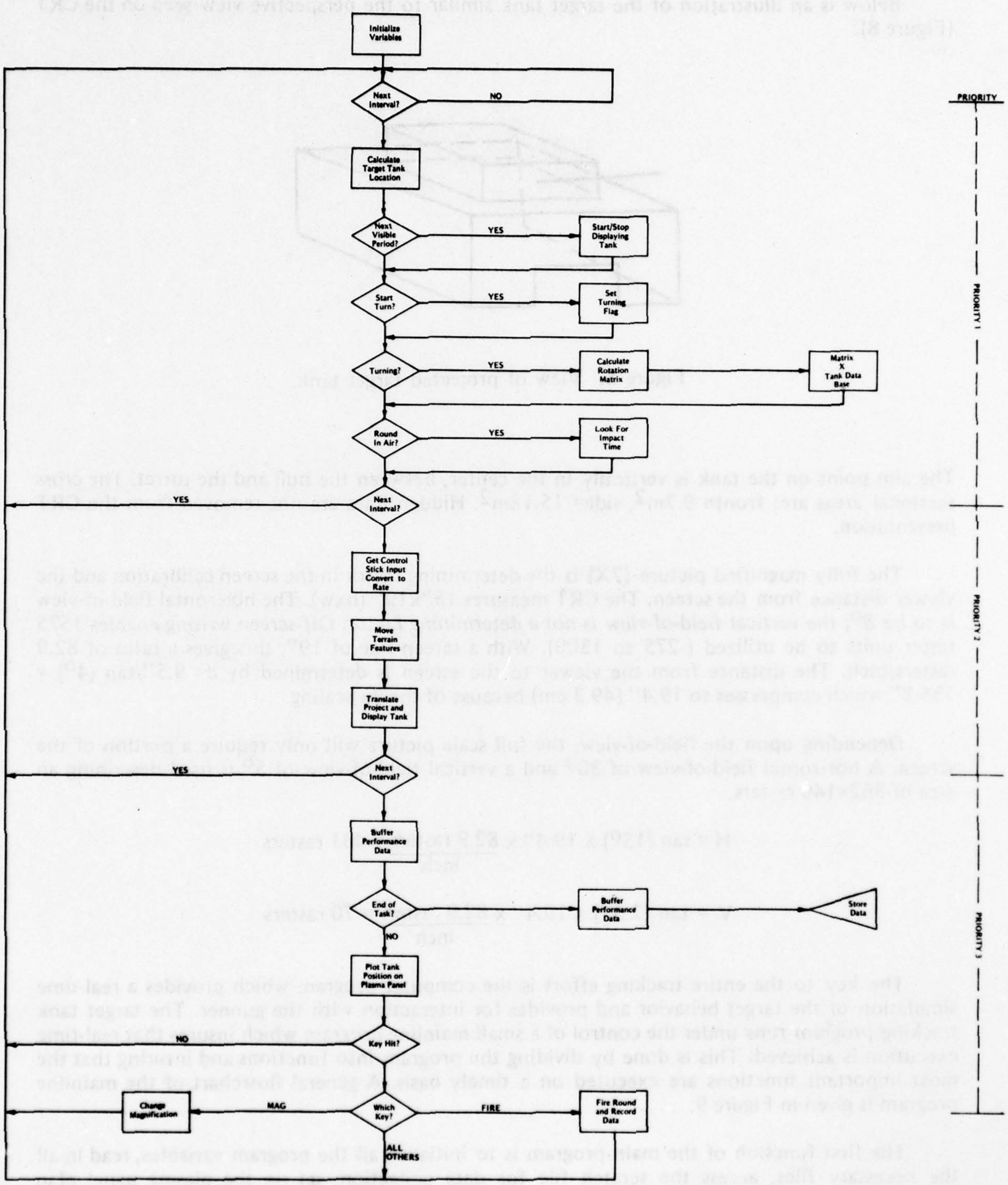

Figure 9. General flowchart of the mainline program.

Priority 1 - must be executed every time interval if necessary.

a. Calculate target location.

b. Initiate a turn.

c. Calculate a new rotation matrix.

d. Multiply tank data base by rotation matrix.

e. Begin visible/not visible period.

f. Look for impact if round in flight.

Priority 2 - execute if time remains.

g. Calculate sight direction.

h. Move terrain features.

i. Project and display tank.

Priority 3 - execute if time remains after Priority 2.

j. Collect and temporarily store data.

k. Plot target tank position on plasma panel.

l. Check for magnification changes.

m. Check for end of scenario.

n. Check for "fire" button push.

Execution of priority 1 functions is essential for the proper continuation of the program. A new target tank location is determined by adding a predetermined increment to the X, Y, and Z coordinates of the tank location. A flag is set if a tank turn is to be initiated during this time interval. If a turn is in progress during this interval, a new rotation matrix is calculated and the tank data base is multiplied by the rotation matrix. The target intervisibility times are checked for the beginning of a new visible/not visible period.

The gunner is given the capability of firing a simulated round at the target tank by pressing the "fire" button.

The mathematical model for the round trajectory can be programmed in any desired way; for example, requiring no lead or calculating lead based on control stick input. A constant velocity round is assumed. Visual and audible feedback is given to the subject at the time of impact to indicate location of round impact. Thirty-seven rounds can be fired and recorded. At the end of the priority 1 functions, if a time interval (66 msec) has elapsed, the program will return to the beginning of the priority 1 routines and follow the same sequence of events.

Priority 2 functions are directed toward displaying the picture. The control stick input registers (X and Y) are polled and the change since the last polling determines the rate at which the sight direction is changing. Figure 10a shows a plot of pulse rate versus force for the control stick currently in use, a dual-axis force transducer. Forces applied to the stick by the gunner generate analog voltages which are converted to a pulse rate and fed into 12-bit up-down counters. The transfer function which converts the rate of change of the registers to a sight direction rate of change is programmable. Presently, the rate of change of the sight varies linearly with the rate of change of the register. This yields a maximum sight turning rate of $\frac{79.5 \text{ mils}}{\text{sec}}$ as seen in Figure 10b.

An important feature of this program is that any control stick can be used in the experimental setup if it can be interfaced with the computer. In addition, flexibility exists to study a wide range of transfer functions from stick input to sight movement.

Corresponding to the new sight direction, the terrain features are then moved on the screen. The target tank data base, already rotated by a priority 1 routine, is translated to the target location and the perspective transformation is applied to each vector in the data base which yields the screen coordinates of the tank. The tank is displayed dependent upon its location and the sight direction. The transformations applied to the tank data base are depicted below:

$$\underset{\text{Tank Data Base}}{\begin{bmatrix} X & Y & Z & 1 \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ & & & \end{bmatrix}} \times \underset{\text{Rotation About X Axis}}{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}} \times \underset{\text{Rotation About Y Axis}}{\begin{bmatrix} \cos\phi & 0 & \sin\phi & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\phi & 0 & \cos\phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}} \times \underset{\text{Translation}}{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -X_T & -Y_T & -Z_T & 1 \end{bmatrix}} = \underset{\text{Transformed Data Base}}{\begin{bmatrix} X^1 & Y^1 & Z^1 & 1 \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ & & & \end{bmatrix}}$$

Screen coordinates are given by:

$$X_s = \frac{X^1 \cdot 1575}{Z^1} + 512 + ITY$$

where (ITX,ITY) = sight direction coordinates

(512,512) = screen center

1575 = total screen rasters

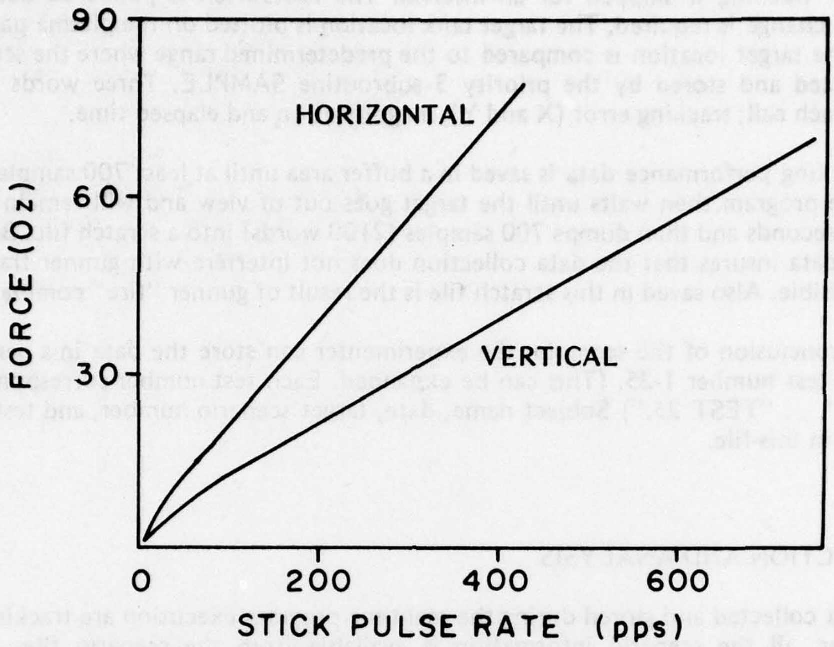

Figure 10a. Stick force versus pulse rate output.

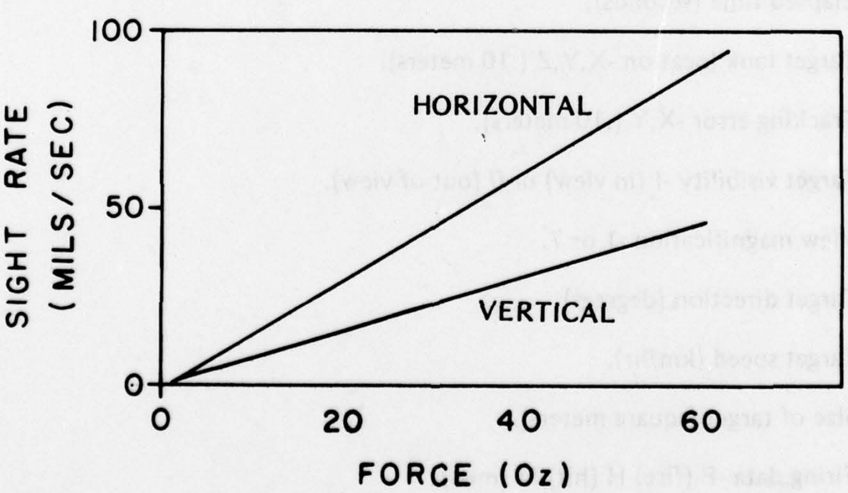

Figure 10b. Sight rate versus stick force.

Figure 10. Stick force.

Priority 3 routines are not directly related to the tracking performance and will not interfere with tracking if skipped for an interval. The footswitch is polled to determine if a magnification change is required. The target tank location is plotted on the plasma panel position display and the target location is compared to the predetermined range where the scenario ends. Data is collected and stored by the priority 3 subroutine SAMPLE. Three words of data are collected on each call; tracking error (X and Y), magnification and elapsed time.

The tracking performance data is saved in a buffer area until at least 700 samples have been collected. The program then waits until the target goes out of view and will remain out of view for at least 2 seconds and then dumps 700 samples (2100 words) into a scratch file. Buffering the performance data insures that the data collection does not interfere with gunner tracking while the target is visible. Also saved in this scratch file is the result of gunner "fire" commands.

At the conclusion of the scenario, the experimenter can store the data in a permanent file by entering a test number 1-25. (This can be expanded. Each test number corresponds to a disk file "TEST 1". . . "TEST 25.") Subject name, date, target scenario number, and test conditions are also saved in this file.

DATA REDUCTION AND ANALYSIS

The data collected and stored during the real-time program execution are tracking error and time. However, all the scenario information is available from the scenario files and can be matched against the tracking performance to provide detailed information about the gunner's performance. This matching of collected data with scenario data is done by the program <u>OUT</u> and the results are stored in files "OUT1". . ."OUT25." This file contains the following information for each time increment:

1. Elapsed time (intervals).
2. Elapsed time (seconds).
3. Target tank location -X,Y,Z (.10 meters).
4. Tracking error -X,Y (.10 meters).
5. Target visibility -I (in view) or 0 (out of view).
6. View magnification -1 or 7.
7. Target direction (degrees).
8. Target speed (km/hr).
9. Size of target (square meters).
10. Firing data -F (fire) H (hit) M (miss).

An example of the data in this file is given in Table 6.

TABLE 6

Target Tracking Performance Data Output

TEST 2 R CAMDEN
TGT PATH 3 OCTOBER 19, 1977
TEST CONDITIONS: HIGH SAMPLING RATE

TIME		* TARGET LOCATION *			TRACKING ERROR		VIEW		SIZE
INTVLS	(SEC)	X	Y	Z	DEVX	DEVY	/MAG	HDG/SPD	(SQM)
518	34.19	36.8	141.5	1914.4	0.5	1.6	1/7	80/ 23	17.75
519	34.25	37.2	141.4	1914.3	0.7	1.6	1/7	80/ 23	17.75
520	34.32	37.6	141.4	1914.2	1.0	1.6	1/7	80/ 23	17.75
521	34.39	38.0	141.4	1914.2	1.2	1.6	1/7	82/ 23	17.52
523	34.52	38.9	141.4	1914.1	1.9	1.6	1/7	84/ 23	17.27
525	34.65	39.7	141.4	1914.0	2.6	1.6	1/7	86/ 23	16.99
527	34.78	40.5	141.4	1913.9	3.3	1.6	1/7	88/ 23	16.70
529	34.91	41.4	141.4	1913.9	4.2	1.4	1/7	90/ 23	16.39
531	35.05	42.2	141.4	1913.9	4.2	1.4	1/7	92/ 23	16.31
533	35.18	43.0	141.4	1913.9	3.5	1.4	1/7	94/ 23	16.63
535	35.31	43.9	141.4	1914.0	2.8	1.6	1/7	96/ 23	16.92
537	35.44	44.7	141.4	1914.1	1.6	1.6	1/7	98/ 23	17.20
539	35.57	45.5	141.4	1914.2	0.9	1.6	1/7	100/ 23	17.46
541	35.71	46.4	141.4	1914.3	1.2	1.6	1/7	102/ 23	17.69
543	35.84	47.2	141.4	1914.5	1.4	1.6	1/7	104/ 28	17.90
545	35.97	48.2	141.5	1914.7	1.6	1.6	1/7	104/ 28	17.90
546	36.04	48.7	141.5	1914.8	1.0	1.4	1/7	104/ 28	17.90
547	36.10	49.2	141.5	1915.0	1.0	1.2	1/7	104/ 28	17.90
548	36.17	49.7	141.5	1915.1	0.3	1.0	1/7	104/ 28	17.90
549	36.23	50.2	141.5	1915.2	0.0	0.9	1/7	104/ 28	17.90
564	37.22	57.7	141.7	1917.1	1.0	0.7	1/7	104/ 28	17.90

The measured tracking error has two components: Target location and sight direction. The tracking error is recorded in whole raster units, since this is the smallest unit of discrete measurement on the CRT. The minimum measurable error occurs when 1 raster unit separates the tank location and the sight direction. As a function of range and magnification, the error (meters and mils) is given by:

$$ERR_{Meters} = \frac{R x Range}{1575 x MAG}$$

$$ERR_{Mils} = \frac{1000 x R}{1575 x MAG}$$

where: R = error in raster units

MAG = magnification (1 or 7)

Range = target range

1575 = total rasters

Most scenarios run between 500 and 2000 meters. Table 7 lists a matrix of minimum measurable errors (1 raster unit on screen):

TABLE 7

Measurable Tracking Error

SCALE		Range (m) 500	2000
1X	Error (mils)	.63	.63
	Error (meters)	.32	1.27
7X	Error (mils)	.09	.09
	Error (meters)	.04	.18

CONCLUSION

This study has determined the viability of this approach as a tool for human factors evaluation of tank fire control and gunner tracking performance. It was shown that we could (1) simulate and display evasive, intermittent, tactical target behavior, (2) control important variables affecting gunner performance, and (3) collect and analyze tracking performance data at a high sampling rate.

The main disadvantage of using a stroke-writing CRT for the display should be eliminated in the near future with the addition of raster scan imaging capability to the HEL command control simulation facility. The ability to display surfaces will greatly improve target masking by the terrain features. The ability to interface with various control sticks and to program any input transfer function provides feasibility in studying various sight control mechanisms.

The basic approach to this area of investigation has been shown to be feasible and should be pursued and expanded.

APPENDIX A

TANK TRACKING PROGRAMS

PROGRAM: SETY

PURPOSE: To calculate and store the Y(altitude) value of the terrain features

DEVICES: None

FILES(Altered): TERRL

SUBROUTINES: None

REMARKS: **Calculates altitude based on formula:**

Alt = (.1) Range -50. where:

Range = terrain feature range in meters

PROGRAM:	PATH
PURPOSE:	To generate and store a target tank course for use in tank tracking program.
DEVICES:	Plasma panel, TTY
FILES: (Accessed)	TERRL
	SCEN
(Altered)	SCEN1 thru SCEN15
SUBROUTINES:	BETW
	DOTURN
	GETTT
	INTERV
	NORM
	OUTL
	RAND
	RNUMB
	SETUP
	SLOCT
	VISIB
	WATNOW
REMARKS:	User inputs X and Z location of target starting point, and a random number seed. A target course is then calculated, avoiding terrain features, and staying within a predetermined area. Target intervisibility intervals are calculated. Tank course can be saved in file 'SCENXX' for use with tank tracking program.

PROGRAM: CHTIME

PURPOSE: To store intervisibility times for a tank course.

DEVICES: CRT, KEYBOARD, function keys

FILES: (Accessed)

TERRL

SCEN1 thru SCEN15

PICT

TABLE

TREE1

TREE2

HILL3

HILL4

(Altered) CHECK

SUBROUTINES:

DATA	OUTL
DISPL	PLOTT
DISPLF	SAMPLE
GETS	SAVET
GETTT	SETG
GRID	SIT1
HERE	SIT7
HOR7	STICK
IMATRX	TABLE
IMUL	TANK
IMX	TDATA
INVIS	TERENT
IPYRA	TERRIN
LODE	TIME
MAGCH	
MAGN	

REMARKS: Tank is automatically tracked through the entire course, and remains visible at all times. Operator key pushes on keyboard will store scenario time in file 'CHECK.' This is used to 'fine tune' the intervisibility times found in the tank course file. Tank course is plotted on plasma panel. Full scale and 7X scale are available.

PROGRAM: T

PURPOSE: Target tank tracking and data collection mainline program

DEVICES: CRT, keyboard, plasma panel, TTY, function keys

FILES: (Accessed) TERRL
SCEN1 thru SCEN15
PICT
TABLE
TREE1
TREE2
HILL3
HILL4
(Altered) SCRACH
TEST1 thru TEST25

SUBROUTINES:

DATA	PLOTT
DISPL	PT
DISPLF	SAMPLE
GETS	SAVET
GETTT	SETG
GRID	SIT1
HOR7	SIT7
IMATRX	STICK
IMUL	TABLE
IMX	TANK
INVIS	TDATA
IPYRA	TERENT
LODE	TERRIN
MAGCH	TIME
MAGN	
OUTL	

REMARKS: Target tank is presented to the observer, who can use full scale or 7X scale CRT picture. The observer tracks the moving tank using the force stick to control the motion of the scene. The tank is turned off whenever it is fully masked by a terrain feature. Tracking error (X & Y), magnification and time are stored in a buffer and periodically transferred to the disk. A new picture is generated at 15 frames/sec; data is collected at 15 samples/sec. Program is stopped when tank moves to within 600 meters of observer.

PROGRAM: OUT

PURPOSE: To create output file with all pertinent tracking performance data

DEVICES: TTY

FILES: (Accessed) TEST 1 thru TEST 25
(Altered) OUT 1 thru OUT 25

SUBROUTINES: GETP

TESTNO

SETD

REMARKS: Merges scenario information with tracking error data to provide comprehensive listing of all pertinent tracking data for each run.

PROGRAM: PLOT

PURPOSE: To plot tracking error & magnification versus time

DEVICES: Plasma panel, TTY

FILES: (Accessed) OUT 1 thru OUT 25

SUBROUTINES: None

REMARKS: Plots total tracking error in mils or meters from center of tank. Indicates magnification in use.

APPENDIX B

TANK TRACKING FILES

FILES

JOB	FILENAME	TYPE	LOCATION	REMARKS
TANK	SCRACH	LOCAL	DISKØ	Temporary data collection file
TANK	TABLE	LOCAL	DISK 1	Sin/COS integer look-up table
TANK	PICT	LOCAL	DISK 1	Target tank description file
TANK	TERRL	GLOBAL	DISK 1	Terrain area data base
TANK	TREE1	LOCAL	DISK 1	
TANK	TREE2	LOCAL	DISK 1	Terrain feature descriptions
TANK	HILL3	LOCAL	DISK 1	
TANK	HILL4	LOCAL	DISK 1	
PATH	SCEN	GLOBAL	DISKØ	Temporary target path file
TANK	SCEN1	GLOBAL	DISK 1	
.	.	.	.	
.	.	.	.	Target tank path/intervisibility file
TANK	SCEN15	GLOBAL	DISK 1	
TANK	TEST1	LOCAL	DISK 1	
.	.	.	.	
.	.	.	.	Permanent data collection file
.	.	.	.	
TANK	TEST25	LOCAL	DISK 1	
TANK	CHECK	LOCAL	DISKØ	Intervisibility times
TANK	OUT1	LOCAL	DISK 1	
.	.	.	.	
.	.	.	.	Permanent data output file
TANK	OUT25	DISK1	DISK 1	